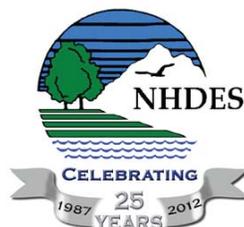


New Hampshire Volunteer Lake Assessment Program

2011 Lakes Region Regional Report



Rust Pond, Wolfeboro, NH



New Hampshire Volunteer Lake Assessment Program 2011 Lakes Region Regional Report

State of New Hampshire
Department of Environmental Services
Water Division
Watershed Management Bureau
P.O. Box 95
29 Hazen Drive
Concord, NH 03302-0095

Thomas S. Burack
Commissioner

Harry T. Stewart
Water Division Direct

Ted Diers
Watershed Management Bureau Administrator

Prepared By:

Sara Steiner
VLAP Coordinator

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INTRODUCTION AND HISTORY

New Hampshire is home to approximately 900 lakes and ponds, and thousands of river miles. Protecting our lakes and rivers is critical to sustaining New Hampshire's drinking water resources, aquatic and natural environments, recreational and tourism industries.

The New Hampshire Department of Environmental Services (DES) recognizes the importance of these waterbodies in maintaining a healthy ecosystem for our current and future generations. Protecting high quality waters and restoring those that are impaired requires coordination and partnership between federal, state and local governments, non-profits, regional commissions, lake associations, and watershed residents.

To help citizens assess the health of New Hampshire's lakes and ponds, DES established the Volunteer Lake Assessment Program (VLAP) in 1985. The program is a volunteer-driven cooperative effort between the State and local governments, lake associations and lake residents. VLAP trains citizen volunteer monitors to collect water quality data at lakes and their associated tributaries on a monthly basis during the summer. VLAP compiles, interprets and reports the data back to state, federal and local governments, lake associations, and lake residents.

VLAP volunteer monitors are invaluable stewards for New Hampshire's lakes. Volunteer monitoring allows DES to establish a strong set of baseline chemical and biological data, determine long-term water quality trends and identify emerging water quality issues. DES acts on these findings through its funding and regulatory programs. Volunteers use this information to educate lake and watershed residents, businesses and local governments on best management practices to keep New Hampshire's lakes and ponds clean. They have been, and will continue to be, a key element in protecting the integrity of New Hampshire's lakes.

PROGRAM OVERVIEW

VLAP is a cooperative program between DES and lake residents and associations. Currently, approximately 500 volunteers monitor water quality at 180 lakes throughout New Hampshire. Interest in the program has grown drastically in the past ten years as citizens have become more aware of the connections between land use activities and water quality. Volunteer monitors continually collect high quality data on their local waterbodies and educate watershed residents.

Volunteer monitors are trained by DES to use monitoring equipment to collect lake water quality data, survey the surrounding watershed, and sample the streams and rivers that are tributaries to the lake. Each of the participating lakes must be visited by a DES biologist on a bi-annual basis. This visit is a valuable event in which the volunteer monitors have an opportunity to discuss water quality and watershed concerns and receive recommendations on potential remediation activities. Also, the event allows DES biologists to perform a field sampling techniques audit to evaluate

volunteer monitor's ability to collect quality data, and to collect information on additional water quality parameters as necessary. Volunteers then sample on their own for the remaining summer months.

To further encourage volunteer monitoring, DES, established partnerships with the Lake Sunapee Protective Association (LSPA), Colby Sawyer College (CSC) in New London, NH, and Plymouth State University (PSU) in Plymouth, NH to operate VLAP satellite laboratories. These satellite laboratories serve as a convenient location for volunteers to borrow sampling equipment and deliver water samples for analysis. These strategic locations serve the Dartmouth Lake Sunapee, North Country and White Mountain regions.

The data gathered by the volunteers are reviewed by DES Quality Assurance Officers and Satellite Laboratory Managers and imported into DES' Environmental Monitoring Database (EMD). During the winter, DES biologists review and interpret the water quality data, perform trend analyses, and compile the results into annual reports. The high quality data gathered through VLAP also helps DES to conduct statewide surface water quality assessments. Assessment results and methodology are published and submitted to the Environmental Protection Agency (EPA) by DES every two years as a requirement of the Clean Water Act.

Once the volunteer monitors receive the data and the annual report for their lake, DES encourages the volunteers to relay that information to their respective associations, organizations, businesses, and local governments. Volunteers are also kept informed of the latest in lake management and water quality issues through an annual newsletter, technical and educational materials, regional workshops, and information on important legislation. In addition, DES biologists give presentations at lake association meetings and participate in youth education events. Educational initiatives, such as those mentioned above, allow volunteers to recognize potential water quality or shoreland violations around the lake and report their findings to DES. Volunteer monitors are dedicated, proactive lake stewards who are concerned for the well-being of their lakes.

MONITORING AND PARAMETER SUMMARY

VLAP encourages the collection of comprehensive data sets on key water quality parameters from participating lakes to determine overall health of the system. The lake and tributaries are sampled several times each year over a period of years. This establishes baseline water quality data and allows for the discernment of long-term water quality trends. These trends depict lake health and provide invaluable information to DES' mission to protect New Hampshire's lakes. The sampling efforts of the volunteer monitors supplement the environmental monitoring efforts of DES. Only through the assistance of volunteer monitors can such a high volume of sampling be accomplished throughout the state.

DES recognizes the importance of collecting data sets that are representative of varying conditions. VLAP has an EPA approved Quality Assurance Project Plan

(QAPP). The QAPP identifies specific responsibilities of DES and volunteers, sampling rationale, training procedures, and data management and quality control. DES and volunteers adhere to the QAPP regime to ensure high quality and representative data sets are collected.

Volunteers collect samples once per month in June, July and August, with some lakes monitored more or less frequently. Samples are collected at approximately the same location each month at each deep spot thermal layer, major tributaries (those flowing year round) and seasonal tributaries during spring run-off. The samples are analyzed for a variety of chemical and biological parameters including: pH, alkalinity, conductivity, chloride, turbidity, total phosphorus, and *E. coli* (optional). Additional in-lake data are also collected at the deep spot including lake transparency (with and without a viewscope), chlorophyll-a, phytoplankton, and dissolved oxygen and temperature profiles. Volunteer monitors are also trained to identify and collect samples of suspicious aquatic plants and cyanobacteria.

Environmental outcomes are measured by making comparisons to established New Hampshire averages and ranges of lake water quality, and state water quality standards. If analytical results for a particular sampling station frequently exceed state water quality averages or standards, then additional sampling to identify potential pollution sources is necessary. Volunteers often conduct storm event sampling, tributary bracket sampling, and spring run-off sampling to better assess watershed health and provide additional data to guide lake management decisions.

Appendix A includes a summary of each monitoring parameter and Appendix B includes recommended best management practices to remediate pollution sources.

LAKES REGION REGIONAL SUMMARY

The Lakes region consists of towns in New Hampshire's Belknap County, southern parts of Carroll and Grafton Counties, and central parts of Merrimack County (Figure 1). The region is home to a large number of lakes and rivers, most notably Lake Winnepesaukee and Newfound Lake. The Pemigewasset and Winnepesaukee Rivers converge as the headwaters of the Merrimack River.

Freshwater resources in the Lakes region provide valuable drinking water and recreational opportunities and play an important role in the regional economy. Freshwater recreation, including boating, fishing and swimming, in the Lakes region generate approximately \$210 million dollars in sales, \$74 million in household income, and 3,313 jobs annually (Nordstrom, 2007). A perceived decline in water quality as measured by water clarity, levels, flows, aesthetic beauty, or overuse could result in approximately \$64.2 million dollars in lost revenue, \$22.7 million in lost household income and 1,023 lost jobs. The Lakes Region generates the largest revenue from summer recreational activities and would stand to lose the most if water quality were perceived to decline (Nordstrom, 2007).

Similarly, a decline in water clarity alone can result in a decrease in New Hampshire lakefront property values. A one meter decrease in water clarity can lead to an average decrease in property values of between 0.9 percent and 6.0 percent in New Hampshire (Gibbs, Halstead, Boyle & Huang, 2002). This may negatively impact property tax revenues, especially in a state

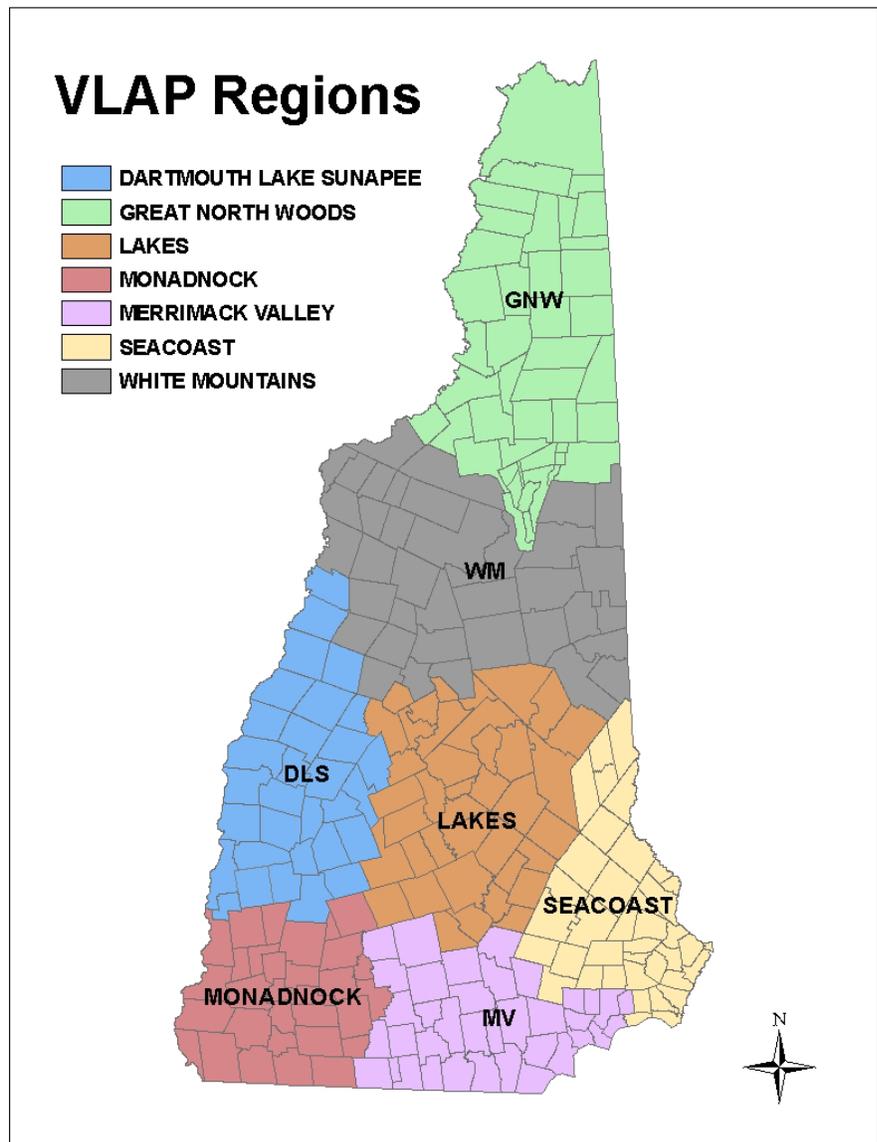


Figure 1. VLAP Regions

where there are approximately 64,000 vacation homes concentrated around the Lakes region (lakes), Seacoast (ocean) and North Country (skiing) (Loder, 2011). According to a 1999 publication of the Society for the Protection of New Hampshire Forests, “The Economic Impact of Open Space in New Hampshire”, vacation homes contribute approximately \$286 million to state and local tax revenues (note: open space includes lakes). For a town with a large number of lakefront homes (vacation or residential), a decline in water clarity can cause decreased property values and local tax revenue.

The Lakes region encompasses all or portions of the Level 8 Hydrologic Unit Code (HUC) Watersheds of the Pemigewasset, Winnepesaukee, Merrimack, and Contoocook Rivers. The HUC boundary defines a specific drainage basin of a major river or series of smaller rivers. There are 18 HUC 8 watersheds in New Hampshire. There are seven VLAP regions (Figure 1). VLAP lakes in the Lakes region include:

Lake Name	Town	Lake Name	Town
Hills Pond	Alton	Clement Pond	Hopkinton
Sunset Lake	Alton	Winnisquam, Pot Isl.	Laconia
Bradley Lake	Andover	Winnisquam, Three Isl.	Laconia
Cole Pond	Andover	Clough Pond	Loudon
Highland Lake	Andover	Pemigewasset Lake	Meredith
Halfmoon Lake	Barnstead	Waukewan Lake, Mayo	Meredith
Locke Lake	Barnstead	Waukewan Lake, Winona	Meredith
Suncook Pond, Lower	Barnstead	Wicwas Lake	Meredith
Suncook Pond, Upper	Barnstead	Lees Pond	Moultonborough
Winnisquam, Mohawk Isl.	Belmont	Winona Lake	New Hampton
Walker Pond	Boscawen	Sondogardy Pond	Northfield
Turee Pond	Bow	Tucker Pond	Salisbury
New Pond	Canterbury	Hermit Lake	Sanbornton
Chestnut Pond	Epsom	Hunkins Pond	Sanbornton
Webster Lake	Franklin	Lower Beech Pond	Tuftonboro
Crystal Lake	Gilmanton	Mirror lake	Tuftonboro
Loon Pond	Gilmanton	Tom Pond	Warner
Sawyer Lake	Gilmanton	Pillsbury Lake	Webster
Shellcamp Pond	Gilmanton	Winnepocket Lake	Webster
French Pond	Henniker	Rust Pond	Wolfeboro

LAND USE AND POPULATION GROWTH

According to the 2010 update of the Society for the Protection of New Hampshire Forests' publication "New Hampshire's Changing Landscape 2010", New Hampshire's population is expected to increase by 180,000 through 2030 (Figure 2). Almost 70 percent of that growth will occur in the Southeastern part of the state, particularly in Merrimack, Hillsborough and Rockingham counties.

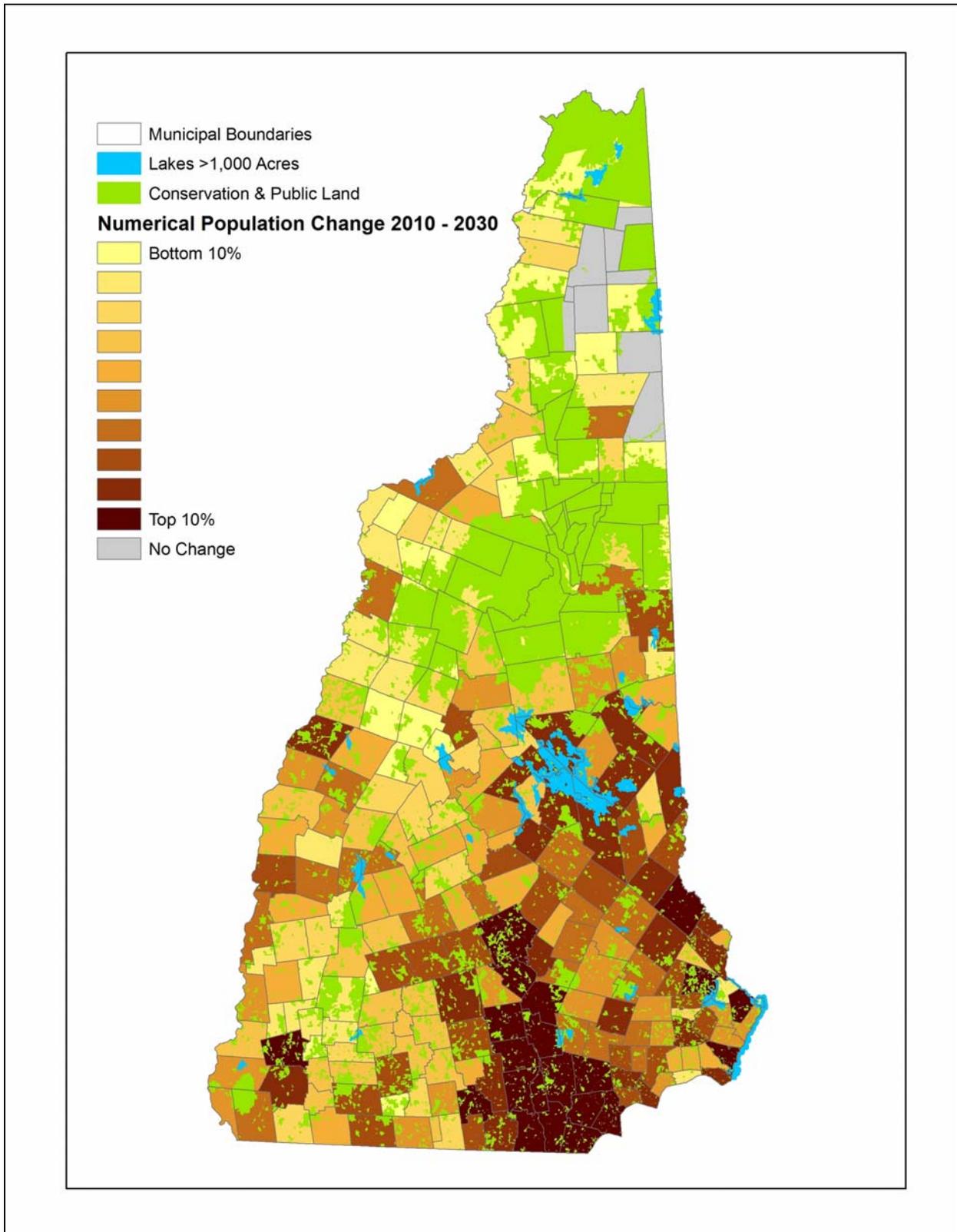
The population is anticipated to grow by approximately 37,000 people in Belknap and Merrimack counties alone by 2030. The majority of growth is estimated to occur around Lake Winnepesaukee in the towns of Wolfeboro, Moultonborough, Meredith, Sanbornton, Gilford, Belmont, and Alton.

The Lake Region is home to over 86,000 acres of water (lakes, river, and wetlands). Approximately 50 percent of this water is located in Belknap County, 26 percent is located in Carroll County, 17 percent is located in Merrimack County, and six percent is located in Grafton County. Over 50,000 acres of water occurs in the towns predicted to experience the heaviest population growth in these four counties, representing approximately 60 percent of the total waterbody acreage in the Lakes region.

Major land use categories in the Lakes region are forest, developed land, and agriculture. Population growth and land use change go hand in hand. Growing populations necessitate land clearing to accommodate new homes, housing complexes, roadways, and commercial businesses. Developed land corresponds to more impervious surfaces such as roadways, driveways, and rooftops. It also corresponds to the loss of tree canopy coverage, unstable sediments, wildlife habitat loss, and vegetative buffer loss. Consequences of development can negatively affect our waterbodies through increases in stormwater runoff, water temperatures, erosion, turbidity and nutrients, as well as shifts in aquatic life, aquatic plant, algae and cyanobacteria growth.

Overall, population growth in the Lakes region could greatly impact a large portion of its waterbodies. Efforts should be made to evaluate current land use activities, infrastructure, and regional water quality. This information should facilitate a plan to accommodate projected population growth while conserving and protecting valuable land and water resources.

Figure 2. NH Population Growth per Town 2010-2030



EXOTIC SPECIES

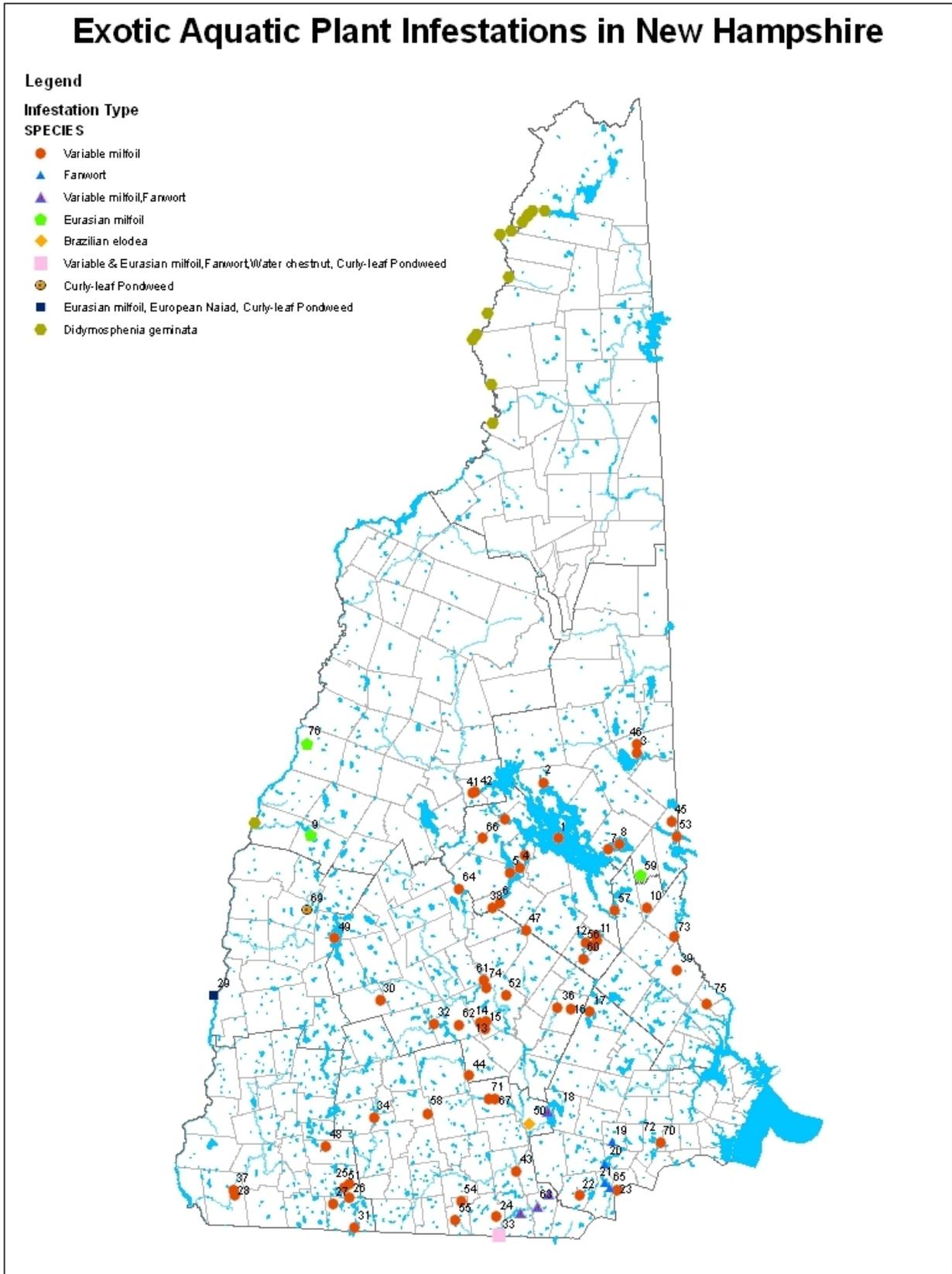
Exotic aquatic species are those plants and animals not native to New Hampshire's waterbodies, such as Variable milfoil and Zebra mussels. Many of these species are invasive and quickly spread throughout the aquatic system, altering habitat and the ecology of the system, often to the detriment of native species. They are a serious threat to the health of New Hampshire's aquatic ecosystem, recreation and tourism industries.

New Hampshire has 85 exotic plant infestations in 76 waterbodies (Figure 3). Those include Variable milfoil, Eurasian milfoil, Brazilian Elodea, Water chestnut, Curly-leaf Pondweed, Fanwort, European Naiad, and Didymo ("Rock Snot"). Variable milfoil inhabits the majority of infested waterbodies, and Didymo, an invasive alga, has now infested 54 river miles in the North Country. Currently, 29 waterbodies in the Lakes Region are infested with an exotic species, which represents the largest number of infestations of any region in the state. All waterbodies have variable milfoil infestations.

The unique nature, invasive tendency, and volume of infestations, heighten the need to prevent new infestations, manage current infestations and engage watershed residents in the Lakes Region. One program that educates the public and engages watershed residents is the DES Weed Watchers Program. The Weed Watchers program has approximately 750 volunteers dedicated to monitoring lakes and ponds for the presence of exotic aquatic plants. Volunteers are trained to survey their lake or pond once a month from May through September. To survey, volunteers slowly boat, or sometimes snorkel, around the perimeter of the waterbody and its islands. Using the materials provided in the Weed Watcher kit, volunteers look for suspicious aquatic plant species. After a trip or two around the waterbody, volunteers have a good knowledge of its plant community and immediately notice even the most subtle change. If a suspicious plant is found, the volunteers send a specimen to DES for identification, either in the form of a live specimen mailed to DES, or as a photograph emailed to the Exotic Species Program Coordinator. Upon positive identification, a biologist visits the site to determine the extent of infestation, initiates a rapid response management technique where possible, and formulates a long-term management plan to control the nuisance infestation.

Another program dedicated to public education and engaging watershed residents is the Lake Host™ program. The Lake Host™ Program is funded through DES and Federal grants. The program was developed in 2002 by NH LAKES and DES to educate and prevent boaters from spreading exotic aquatic plants to waterbodies in New Hampshire. Since then, the number of participating waterbodies has doubled, the number of volunteers involved and boats inspected has quadrupled, and the number of "saves" (exotic plants discovered) has consistently increased. The program is invaluable in educating boaters, preventing recreational hazards, avoiding property value and aquatic ecosystem decline, addressing aesthetic issues, and saving costly remediation efforts.

Figure 3. NH Exotic Aquatic Plant Infestations



GEOMORPHOLOGY AND CLIMATE

Chemical, physical and biological properties of lakes often reflect how they were formed. Lake formation can occur in a variety of ways. In New Hampshire, most lakes were formed during the last ice age as glaciers retreated. Lakes were also formed from rivers (oxbow), and were man and animal made (impoundments, dams and beavers). These formations create distinct lake morphology, such as length, width, area and volume that affect the lake's ability to adapt to shifts in climate and land use.

Along with morphological characteristics of lakes, the bedrock and sediment geology is also important in understanding lake properties. Underlying geological properties can affect the pH and acid neutralizing capacity (ANC) of our surface and groundwater. New Hampshire is typically referred to as the "Granite State" because the bedrock geology consists of variations of Igneous Rock high in granite content and typically contributes to a lower pH and less capacity to buffer acidic inputs such as acid rain. Metamorphic rocks make up the remainder of bedrock geology and consist of slate, schist, quartzite and carbonate rocks which tend to contribute to a more neutral pH and better buffering capacity.

Along with bedrock geology, climate also drives multiple processes in lake systems. Lakes respond to shifting weather conditions such as sunlight, rainfall, air temperature, and wind and wave action in various ways. This variability is reflected in the types and number of biological communities present, and chemical and physical properties of the lake system. It is essential that we understand how these factors influence water quality data collected at individual lake systems. Therefore, volunteers record pertinent weather data, rain and storm event totals on field data sheets while sampling.

To summarize the Lakes region climate conditions in 2011, the sampling season was warm and wet, except for July which was hot and dry. These observations are based on air and rainfall data recorded in Concord, NH and surface water temperatures recorded by VLAP (Table 1). Average air temperatures in May, July, August, and September were warmer than historical averages, while June was slightly below average. Overall, the 2011 average summer air temperature was 1.0° warmer than the historical average. Surface water temperatures in 2011 were well above average in July and August and were 1.6° warmer than the historical regional average.

Table 1. Current Year and Historical Average Temperature and Precipitation Data for Lakes Region

	May	June	July	August	September	Summer
2011 Average Air Temperature (°F)	69.3	76.6	85.3	81.0	74.7	77.4
Annual Average Air Temperature (°F)	68.9	77.4	82.3	80.9	72.6	76.4
2011 Average Surface Water Temperature (°F)	-----	71.0	78.5	76.6	-----	75.4
Annual Average Surface Water Temperature (°F)	-----	71.3	75.2	74.9	-----	73.8
2011 Precipitation (in.)	4.56	3.91	1.22	7.52	3.77	4.19
Annual Average (in.)	3.66	3.68	3.74	3.18	3.38	3.53

The 2011 monthly summer rainfall amounts were above average in May, June, August and September. However, July through the end of August marked a period of drought-like conditions, until Tropical Storm Irene dumped approximately 3.5 inches of rain in 24 hours at the end of August. Tropical Storm Irene also caused severe flooding and damage in the northern and western portions of New Hampshire. The above average rainfall likely led to an increase in lake turbidity, decrease in water clarity, and an increase in phosphorus and algal growth.

MONITORING AND ASSESSMENT

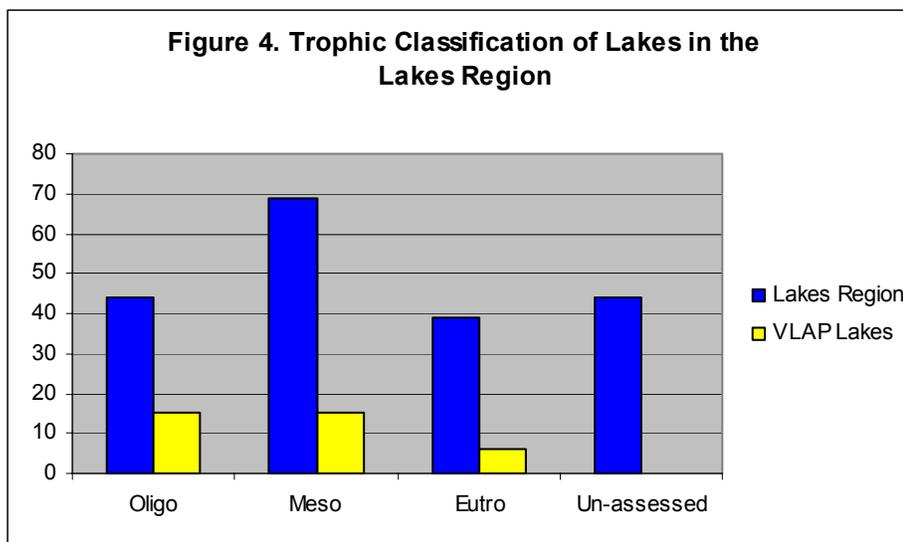
New Hampshire considers public waters to be great ponds or artificial impoundments greater than 10 acres in size, rivers, streams and tidal waters. The Lakes region consists of 196 lakes, or great ponds, and 36 of those lakes participate in VLAP. Data on the remaining 80 percent of lakes are sparse, being only occasionally sampled through the DES Lake Survey Program.

The DES Lake Survey Program monitors NH's lakes on a rotating basis, with the goal of conducting a comprehensive lake survey every 10 to 15 years. The surveys compile chemical, biological and morphological data. The data are used to assign a lake trophic class to each waterbody.

The trophic class provides an assessment of how "aged" a lake is and can provide information on how population growth and human activities may be accelerating the aging process, also known as lake eutrophication.

Three trophic classes are used to assess a lake's overall health, Oligotrophic, Mesotrophic and Eutrophic. Oligotrophic lakes have high dissolved oxygen levels (> 5 mg/L), high transparency (> 12 ft.), low chlorophyll-a concentrations (< 4 mg/L), low phosphorus concentrations (< 10 ug/L), and sparse aquatic plant growth. Eutrophic lakes have low levels of dissolved oxygen (< 2 mg/L), low transparency (< 6 ft.), high chlorophyll-a concentrations (> 15 mg/L), high phosphorus concentrations (> 20 ug/L), and abundant aquatic plant growth. Mesotrophic lakes have characteristics that fall in between those of Oligotrophic and Eutrophic lakes for the parameters listed.

The trophic class breakdown of the Lakes region is shown in Figure 4. Forty-four lakes are Oligotrophic, 69 Mesotrophic, 39 Eutrophic, and 44 lakes are un-assessed for trophic classification due to lack of data. Fifteen Oligotrophic, 15 Mesotrophic and six Eutrophic lakes participate in VLAP. Approximately 60 percent of the Lakes region lakes are classified as Oligotrophic and Mesotrophic; however only 25 percent of those lakes participate in VLAP or a similar monitoring program. As human activities in watersheds accelerate lake aging, it is imperative to keep a close eye on the health of those lakes in the Oligotrophic and Mesotrophic classes. Efforts should also be made to gather data on the un-assessed waterbodies. Protecting a lake and preventing lake aging is much more cost-effective than restoring a damaged lake.



VLAP WATER QUALITY DATA INTERPRETATION

The Lakes Region is home to 36 lakes and ponds that participate in VLAP. Volunteer monitors at each lake collect comprehensive data sets at the deepest spot of the lake and from streams entering or exiting the lake. Deep spot sample collection is representative of overall lake quality conditions and provides insight into how the lake responds to localized events such as stormwater and drought. Deep spot data are used to establish long term water quality trends and to provide information into the overall health of the waterbody. Stream sample collection is representative of what flows into the lake from the surrounding watershed. Stream data are used to identify potential watershed pollution problems so that remediation actions occur before they negatively impact the overall health of the waterbody.

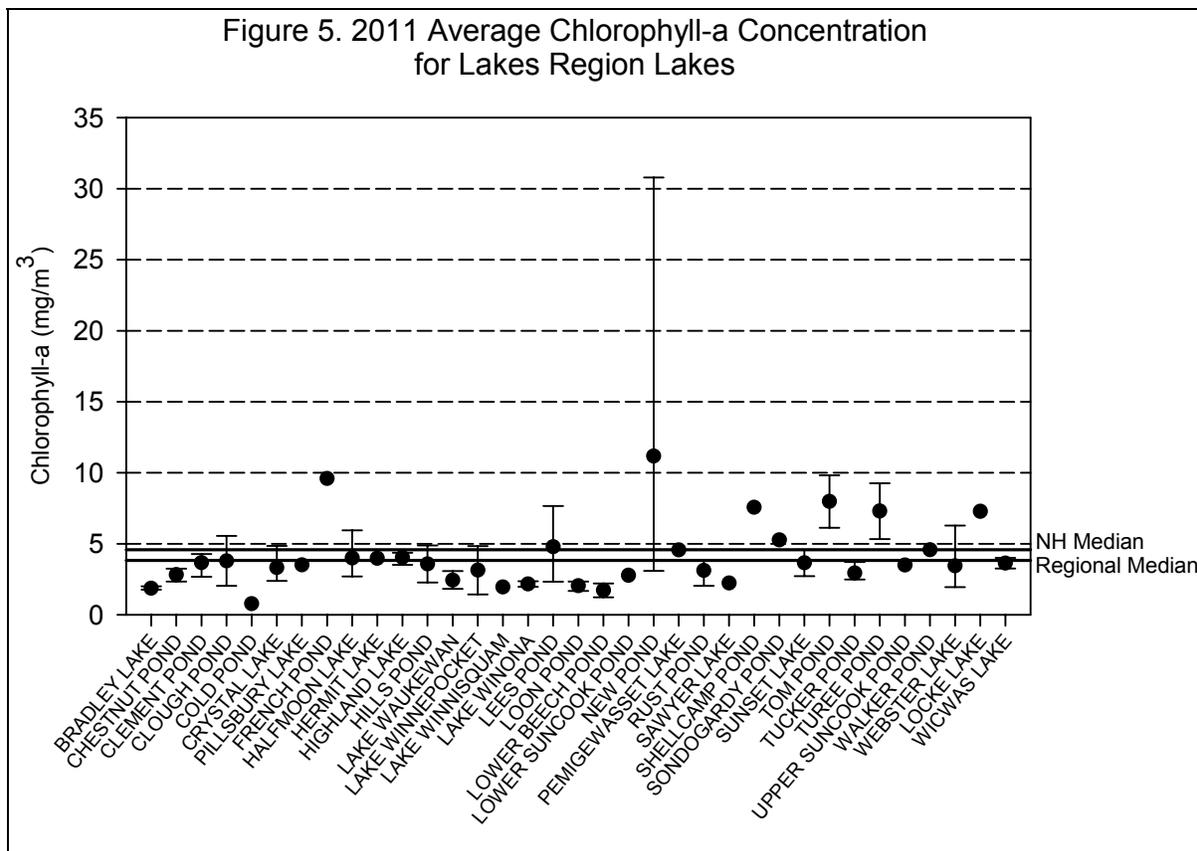
The following section provides a summary of the VLAP monitoring parameters, long-term water quality trends, and an analysis of the current year and historical data for the VLAP lakes and ponds in the Lakes region compared with regional and state medians. The deep spot data for the epilimnion, or surface water layer, is compared to the New Hampshire median to provide an understanding of how the quality of your lake deep spot compares to other New Hampshire lake deep spots. Similarly, the epilimnion data are compared to the regional median to provide an understanding of how the quality of your lake deep spot compares with other local lakes. Median values were utilized to represent historical state and regional conditions as the value tends to better represent the actual middle number while minimizing the effects of outlier values. Average annual lake and regional values are then compared to the historical medians.

A complete list of monitoring parameters and how to interpret data are included in Appendix A.

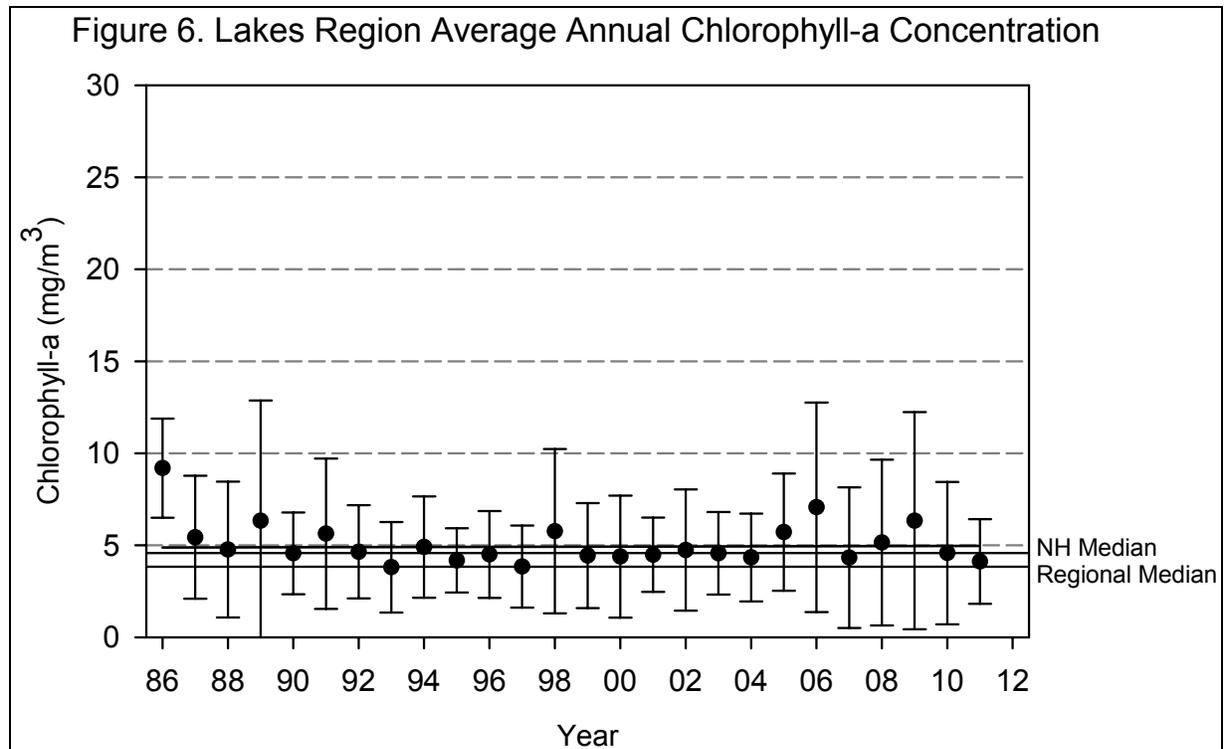
Annual and Historical Chlorophyll-a Results

Algae are microscopic plants that are naturally found in the lake ecosystem. Algae and cyanobacteria contain chlorophyll-a, a pigment used for photosynthesis. The measurement of chlorophyll-a in the water provides an estimation of the algal and/or cyanobacteria abundance or lake productivity. **The median summer chlorophyll-a concentration for New Hampshire’s lakes and ponds is 4.58 mg/m³. The median chlorophyll-a concentration for the Lakes Region is 3.83 mg/m³.**

The 2011 average chlorophyll-a concentration for each lake in the Lakes region are represented in Figure 5. The regional and state medians are provided for reference. The average chlorophyll-a concentration at 24 lake deep spot stations are equal to or below the regional median and are typically representative of good water quality. Three lakes have average chlorophyll-a concentrations between the state and regional medians, and eight lakes experienced average chlorophyll-a concentrations above the state median. Typically, chlorophyll-a concentrations that exceed 5.0 mg/m³ are considered higher than desirable. Seven lakes experienced average chlorophyll-a concentrations above 5.0 mg/m³. Three of those lakes are classified as Eutrophic and typically experience annual cyanobacteria blooms. The chl-a concentration at Hunkins Pond in Sanbornton reached 87.13 mg/m³, however that value was not included in Figure 5 to allow better graphical representation of all lakes. Overall, approximately 80 percent of the sampled deep spots have chlorophyll-a concentrations representative of Oligotrophic and Mesotrophic classifications.



The average annual chlorophyll-a concentrations for the Lakes region are represented in Figure 6. Average annual chlorophyll-a concentrations have generally remained between 3.0 and 5.0 mg/m³ since 1986. Please note that this does not include data from Hunkins Pond in Sanbornton. Hunkins Pond is a shallow farm pond which experiences annual cyanobacteria blooms and phosphorus loading several times higher than the regional lakes. Utilizing the data is not representative of the regional average and was removed to better represent regional characteristics. Visual observation of the trend line indicates regional chlorophyll-a concentrations, and therefore algal growth, are relatively stable over time.



Chlorophyll-a Trend Analysis

Lakes region lakes with 10 or more consecutive years of data were subject to statistical analyses to determine whether water quality trends were significantly improving, degrading, stable, or variable, meaning values fluctuate between years and there is no clear trend. Chlorophyll-a trends were assessed for approximately 26 deep spots at 25 lakes in the region. Eleven lakes did not have 10 or more consecutive years of data, therefore, trend analyses were not conducted. Approximately 70 percent of the Lakes region lakes have 10 or more years of consecutive data collection on record.

Table 2 represents the Lakes region chlorophyll-a trends with the direction of the arrow indicating whether chlorophyll increased, decreased, or remained stable. Note that improving trends reflect a decrease in chlorophyll levels, and vice-versa. Approximately 90 percent of lake deep spots have a stable or variable chlorophyll-a trend, meaning the chlorophyll-a concentrations have not significantly increased or

decreased. Chlorophyll-a concentrations are typically related to phosphorus concentrations because as phosphorus increases, more algal growth occurs. The stable chlorophyll-a trends are a positive sign for the region.

Table 2. Chlorophyll-a Trends in Lakes Region

Lake Name	Improve	Degrade	Stable	Variable
Crystal Lake	▼			
French Pond		▲		
Cole Pond			▶▶	
Halfmoon Lake			▶▶	
Highland Lake			▶▶	
Loon Pond			▶▶	
Lower Beech Pond			▶▶	
Rust Pond			▶▶	
Sunset Lake			▶▶	
Tucker Pond			▶▶	
Lake Winnisquam, Pot Island			▶▶	
Chestnut Pond				★
Clement Pond				★
Clough Pond				★
Hermit Lake				★
Hills Pond				★
Lees Pond				★
New Pond				★
Sondogardy Pond				★
Tom Pond				★
Lake Waukewan, Mayo				★
Lake Waukewan, Winona				★
Webster Lake				★
Wicwas Lake				★
Winnepocket Lake				★
Winona Lake				★

Annual and Historical Transparency Results

Volunteer monitors use the Secchi disk, a 20 cm disk with alternating black and white quadrants, to measure how far a person can see into the water. Transparency, a measure of water clarity, can be affected by algae and sediment in the water, as well as the natural color of the water. Transparency may also be measured using a viewscope, a cylindrical tube, designed to decrease surface water properties that may cause difficulty in viewing the Secchi disk. A comparison of transparency readings collected with and without the use of a viewscope shows that the viewscope typically increases the depth to which the Secchi disk can be seen into the lake, particularly on sunny and windy days. **The median summer transparency for New Hampshire's lakes and ponds is 3.20 meters. The median transparency for the Lakes region is 4.30 meters.**

Tropical Storm Irene passed through New England at the end of August, dumping several inches of rain and causing major flooding in some areas. This likely resulted in a lower overall transparency for many of the region's waterbodies as stormwater runoff transports exposed and unstable sediments and debris. Figure 7 below represents the 2011 average transparency for each lake in the Lakes region compared with state and regional medians.

The average transparencies at 11 lake deep spots are below the state median and are typically representative of poor water quality conditions. Twelve lakes fall between the state and regional median, and 13 are above the regional median and are typically representative of good water quality. Overall lake depth plays an important role when interpreting transparency data. Shallow lakes will typically report lower transparencies than deeper lakes, yet these waterbodies may be quite clear. A better representation would be to look at how transparency changes over time.

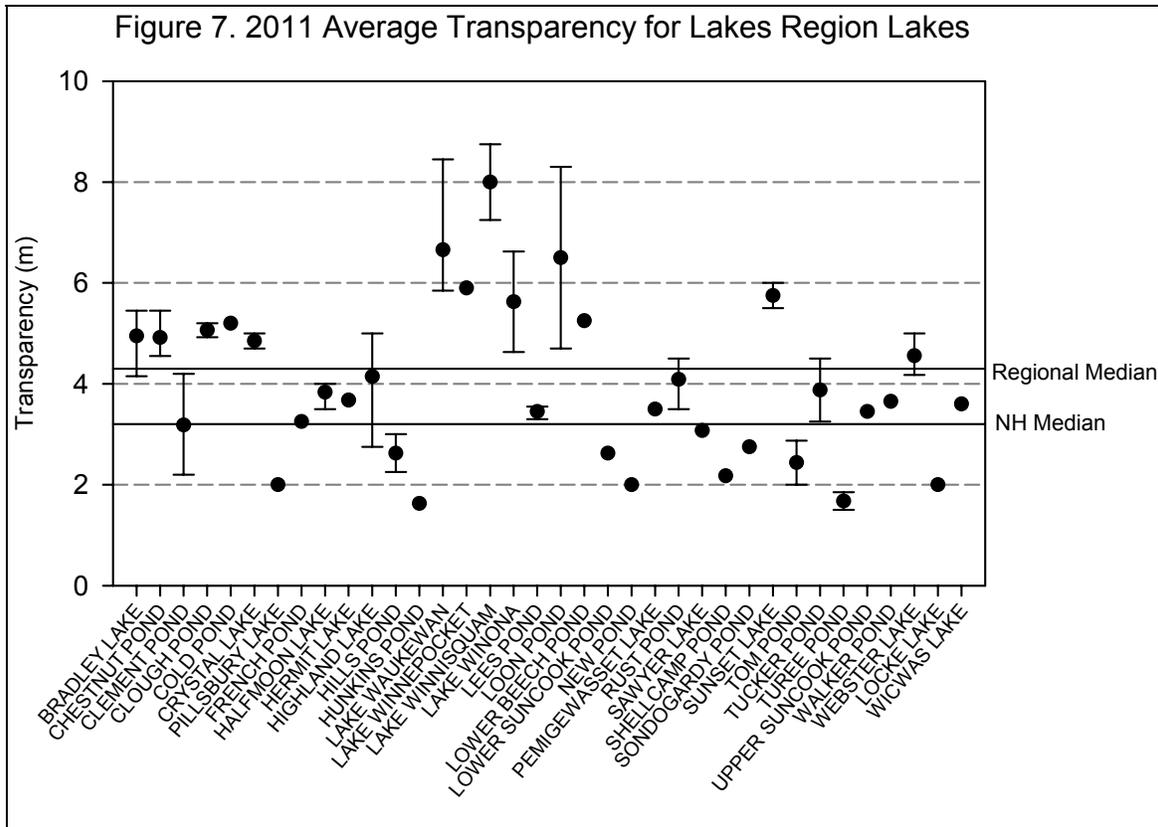
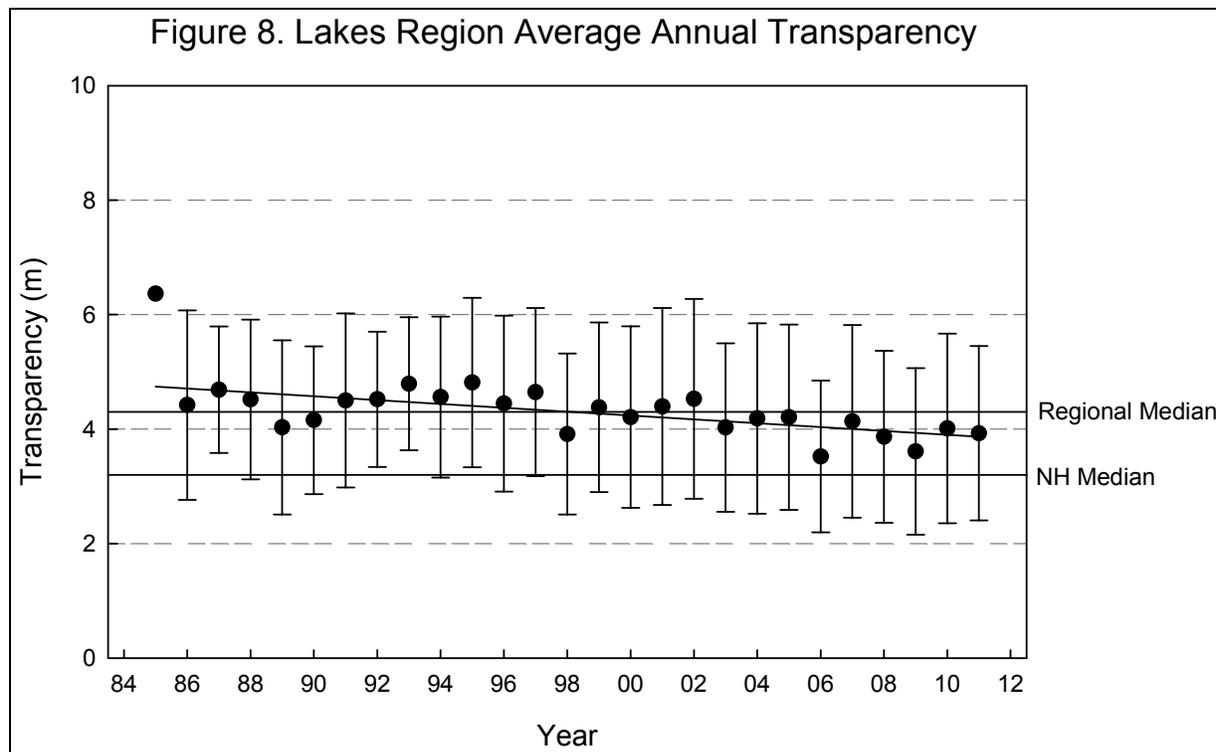


Figure 8 represents the average annual transparency for the Lakes region. Average transparencies for the region remained at or above the regional median from 1985 through 2002. Average transparencies have decreased from 2003 to the present and remain between the regional and state medians. Visual observation of the trend line indicates regional transparency has decreased over time.



Transparency Trend Analyses

Lakes Region lakes with 10 or more consecutive years of data were subject to statistical analyses to determine whether water quality trends were significantly improving, degrading, stable, or variable, meaning values fluctuate between years and there is no clear trend. Transparency trends were assessed for 26 deep spots at 25 lakes in the region. Approximately 70 percent of the Lakes region lakes have 10 or more years of consecutive data collection.

Table 3 represents the Lakes region transparency trends with the direction of the arrow indicating whether the transparency increased, decreased, or remained stable. Note that improving trends reflect an increase in transparency, and vice-versa. Fifty-seven percent of lake deep spots have a stable transparency trend, meaning the transparency has not significantly improved or degraded. Twenty percent of the lake deep spots have a degrading trend, meaning transparency has worsened (decreased) over time. And only one lake has an improving transparency trend, meaning transparency has improved (increased) over time.

Transparency, or water clarity, is typically affected by the amount of algae, color, and particulate matter within the water column. The stable transparency trends for the

region are a positive sign; however transparency at 20 percent of the lake deep spots is degrading, or getting worse. Only 4 percent of Lakes region lakes are experiencing increased algal growth which does not explain the worsening transparency. This suggests that the worsening transparency may be explained by an increase in suspended sediments. Stormwater runoff can transport exposed and unstable sediments and other debris to lake systems. It is imperative to identify potential areas of concern in the watershed and utilize best management practices to control stormwater and erosion. Please refer to Appendix B for reference material on do-it-yourself stormwater best management practices.

Table 3. Transparency Trends in Lakes Region

Lake Name	Improve	Degrade	Stable	Variable
Clough Pond	▲			
French Pond		▼		
Hills Pond		▼		
Rust Pond		▼		
Sunset Lake		▼		
Webster Lake		▼		
Chestnut Pond			▶▶	
Clement Pond			▶▶	
Cole Pond			▶▶	
Crystal Lake			▶▶	
Halfmoon Lake			▶▶	
Hermit Lake			▶▶	
Highland Lake			▶▶	
Lake Waukewan, Mayo			▶▶	
Lake Waukewan, Winona			▶▶	
Lake Winnisquam, Pot Island			▶▶	
Loon Pond			▶▶	
Lower Beech Pond			▶▶	
Tom Pond			▶▶	
Tucker Pond			▶▶	
Winnepocket Lake			▶▶	
Lees Pond				★
New Pond				★
Sondogardy Pond				★
Wicwas Lake				★
Winona Lake				★

Annual and Historical Total Phosphorus Results

Phosphorus is typically the limiting nutrient for vascular plant and algal growth in New Hampshire's lakes and ponds. Excessive phosphorus in a pond can lead to increased plant and algal growth over time. **The median summer epilimnetic (upper layer) total phosphorus concentration of New Hampshire's lakes and ponds is 12 ug/L. The median epilimnetic total phosphorus concentration for the Lakes region is 8 ug/L.**

Figure 9 represents the 2011 average epilimnetic total phosphorus concentration for the Lakes region lakes. The regional and state medians are provided as reference. The regional median is considerably lower than the state median, and is considered to be representative of Oligotrophic conditions. Eighteen lakes experienced average phosphorus concentrations equal to or below the regional median. Nine lakes experienced average phosphorus concentrations between the regional and state medians, and nine lakes experienced average phosphorus concentrations equal to or greater than the state median. Three of those lakes experienced average phosphorus concentrations above 20 ug/L representative of Eutrophic conditions. Overall, regional epilimnetic phosphorus concentrations are relatively low and representative of Oligotrophic and Mesotrophic conditions.

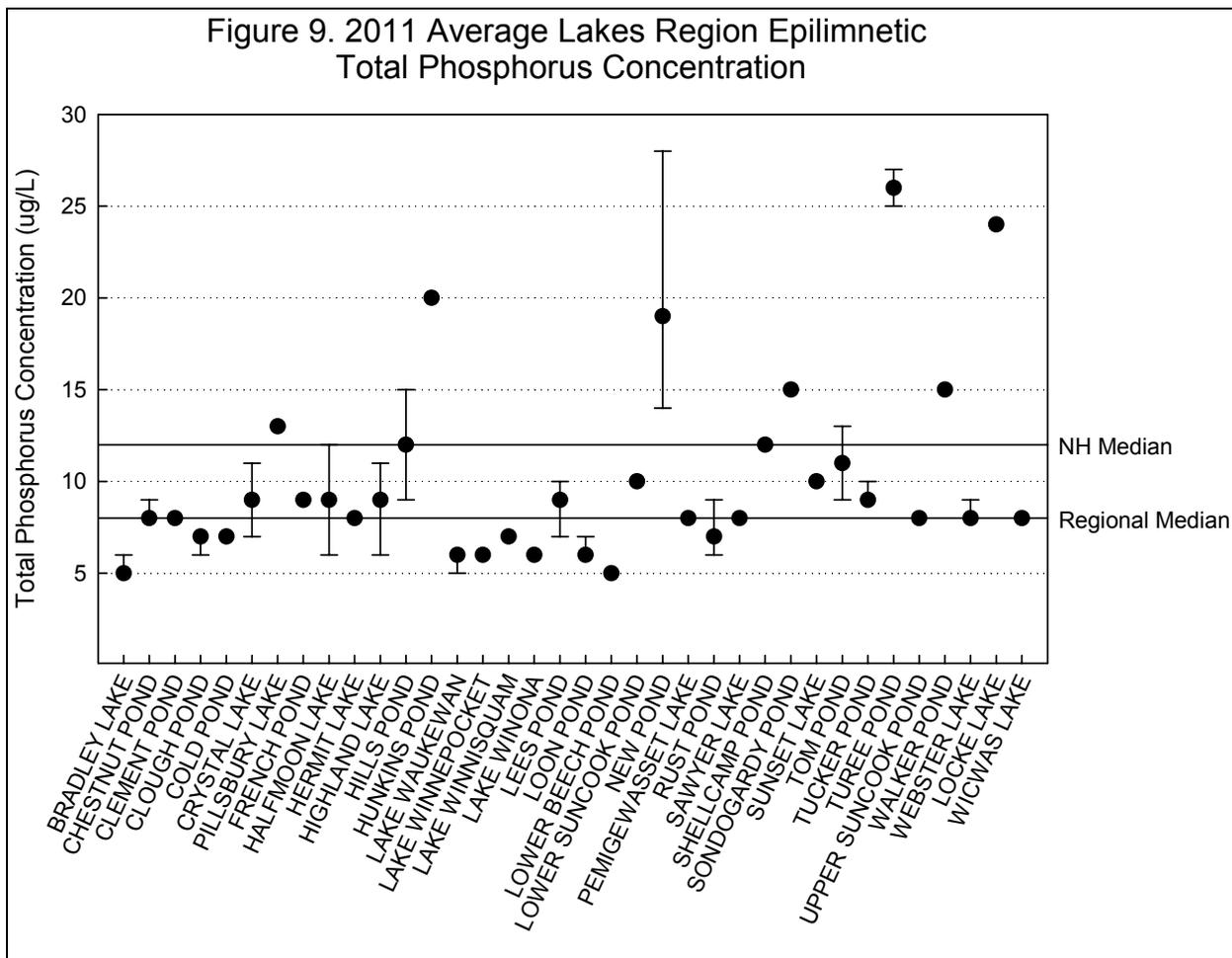
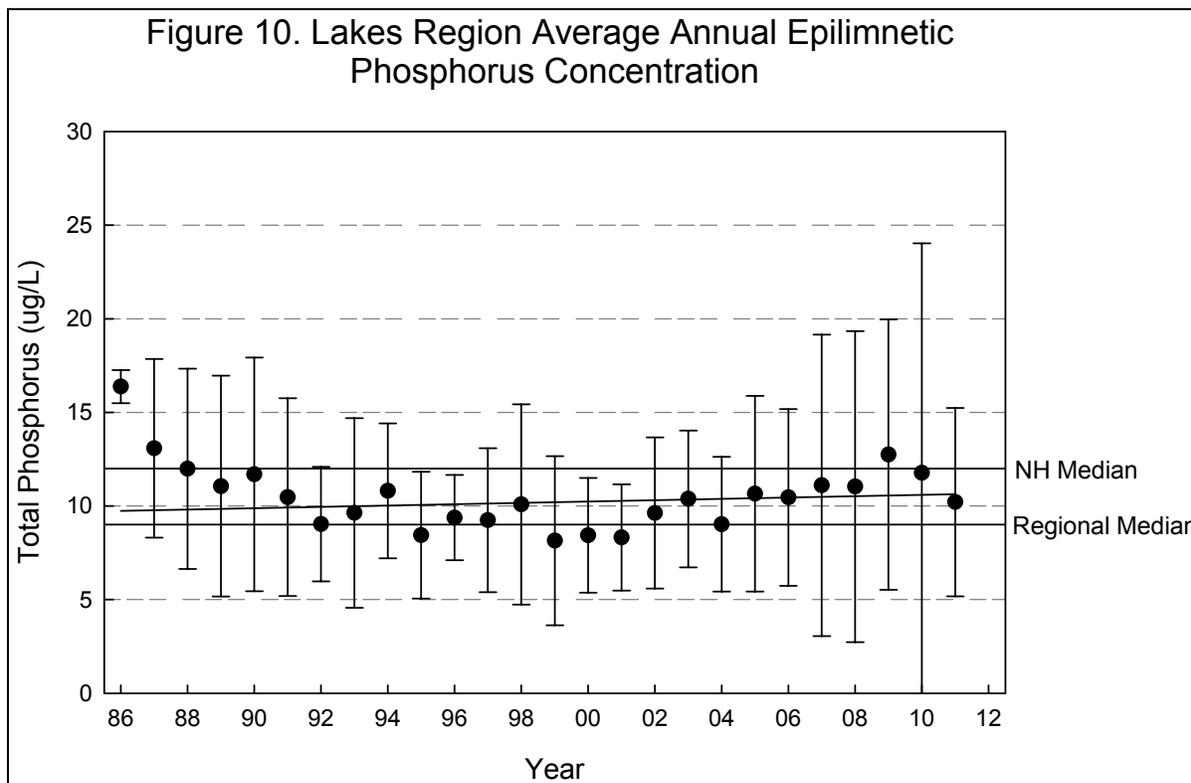


Figure 10 represents the average annual epilimnetic phosphorus concentration for the Lakes region. The average annual epilimnetic phosphorus concentrations have generally remained between the regional and state median since 1986. The annual average has fluctuated between 8 ug/L and 16 ug/L but tends to be around 10 ug/L, which is on the border of Oligotrophic/Mesotrophic conditions. Visual observation of the trend line indicates regional epilimnetic phosphorus has remained relatively stable over time.



Epilimnetic Phosphorus Trend Analyses

Lakes region lakes with 10 or more consecutive years of data were subject to statistical analyses to determine whether water quality trends were significantly improving, degrading, stable, or variable, meaning values fluctuate between years and there is no clear trend. Epilimnetic total phosphorus trends were assessed for approximately 25 deep spots at 24 lakes in the region. Approximately 70 percent of the Lakes region lakes have 10 or more years of consecutive data collection. This allows a more accurate picture of regional water quality trends.

Table 4 represents the Lakes region epilimnetic total phosphorus trends with the direction of the arrow indicating whether the phosphorus has increased, decreased, or remained stable. Note that improving trends reflect a decrease in phosphorus levels, and vice-versa. Approximately 80 percent of lake deep spots in the region have a stable or variable epilimnetic phosphorus trend, meaning the phosphorus concentrations have not significantly improved or degraded since monitoring began.

Twelve percent of the lake deep spots have an improving total phosphorus trend, meaning phosphorus concentrations have significantly decreased, which is a positive sign. A more positive sign is that only one lake deep spot has a significantly degrading (increasing) phosphorus trend, however efforts should be made to identify and remediate sources of phosphorus at this lake.

Increasing epilimnetic phosphorus trends are often a result of phosphorus-enriched stormwater runoff related to increased watershed development. An increase in watershed development often results in an increase in impervious surfaces and unstable sediments. This contributes to an increase in stormwater runoff and sedimentation to rivers and lakes. Efforts should be made to adopt watershed ordinances to limit stormwater runoff and other phosphorus contributions. Watershed residents should be educated on utilizing and installing best management practices to control stormwater runoff from their own properties. For more information and resources to control phosphorus loading refer to Appendix B.

Table 4. Epilimnetic Total Phosphorus Trends in Lakes Region

Lake Name	Improve	Degrade	Stable	Variable
Halfmoon Lake	▼			
Rust Pond	▼			
Lake Winnisquam, Pot Island	▼			
Sodogardy Pond		▲		
Chestnut Pond			▶▶	
Clough Pond			▶▶	
Crystal Lake			▶▶	
Hermit Lake			▶▶	
Highland Lake			▶▶	
Hills Pond			▶▶	
Lees Pond			▶▶	
Loon Pond			▶▶	
Lower Beech Pond			▶▶	
Sunset Lake			▶▶	
Tucker Pond			▶▶	
Lake Waukewan, Mayo Stn.			▶▶	
Webster Lake			▶▶	
Winnepocket Lake			▶▶	
Winona Lake			▶▶	
Clement Pond				★
French Pond				★
New Pond				★
Tom Pond				★
Lake Waukewan, Winona Stn.				★
Wicwas Lake				★

Dissolved Oxygen Data Analysis

The presence of dissolved oxygen is vital to bottom-dwelling organisms as well as fish and amphibians. If the concentration of dissolved oxygen is low, typically less than 5 mg/L, species intolerant, meaning sensitive, to this situation, such as trout, will be forced to migrate closer to the surface where there is more dissolved oxygen but the water is generally warmer, and the species may not survive. Temperature and time of day also play a role in the amount of dissolved oxygen in the water column. Water can hold more oxygen at colder temperatures than at warmer temperatures. Therefore, a lake will typically have a higher concentration of dissolved oxygen during the winter, spring, and fall than during the summer. Oxygen concentrations are typically lower overnight than during the day. Plants and algae respire (use oxygen) at night and photosynthesize (produce oxygen) during the day. Dissolved oxygen levels may shift depending on the abundance of aquatic plants and algae in the littoral (near shore) and pelagic (deep water) zones.

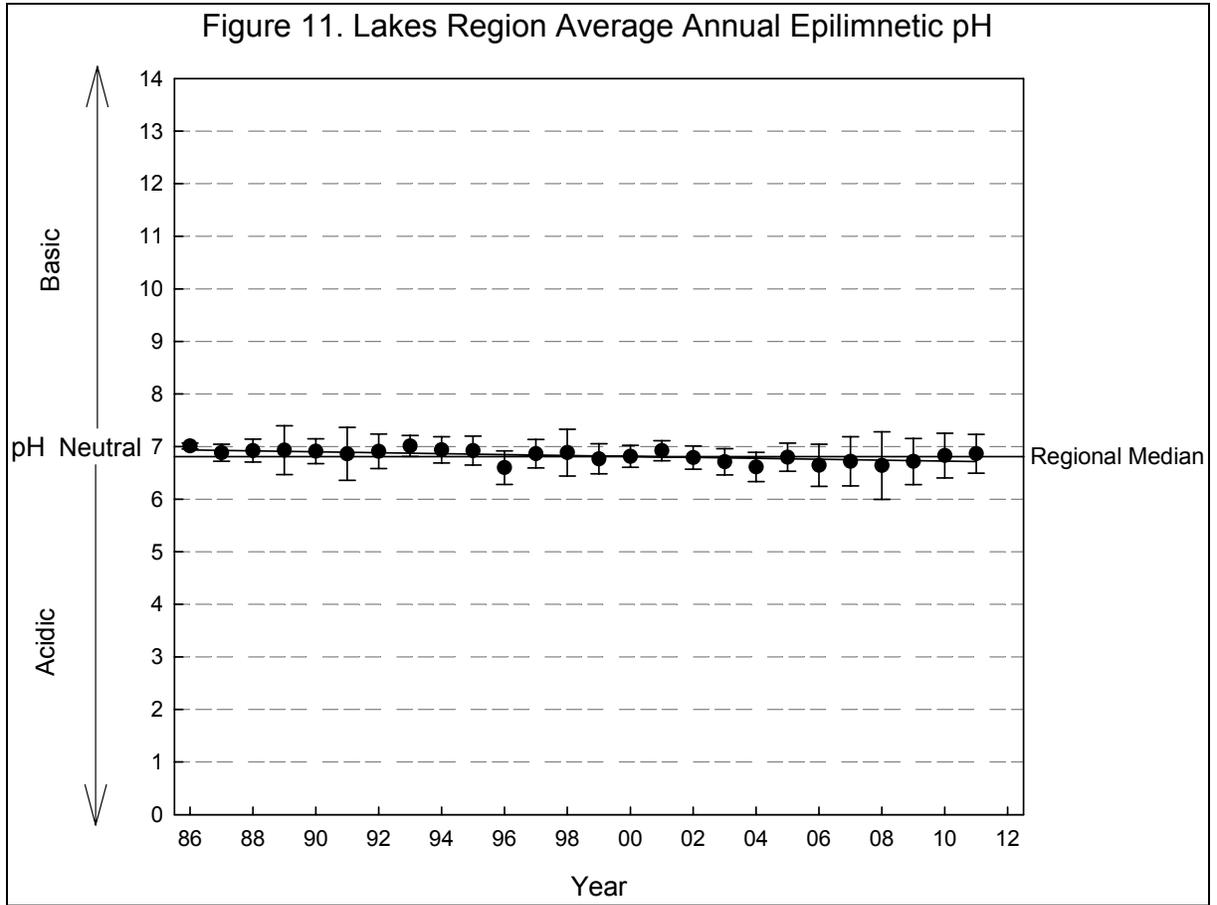
Dissolved oxygen and temperature profiles are collected at VLAP lakes on an annual or bi-annual basis. The average dissolved oxygen levels for the Lakes region is 6.38 mg/L, which is sufficient to support a wide range of aquatic life. For additional information regarding dissolved oxygen please refer to Appendix A.

Annual and Historical Deep Spot pH Data Analysis

pH is measured on a logarithmic scale of 0 (acidic) to 14 (basic). pH is important to the survival and reproduction of fish and other aquatic life. A pH below 6.0 typically limits the growth and reproduction of fish. A waterbody is considered impaired for aquatic life when the pH falls below 6.5 or above 8.0. **The median epilimnetic pH for New Hampshire's lakes is 6.6, which indicates that the state surface waters are slightly acidic. The median epilimnetic pH for the Lakes Region is 6.81.**

Figure 11 represents the average annual pH value for the Lakes region compared with the regional median. The 2011 average epilimnetic pH value of the Lakes region was 6.86, which means that the water is approximately neutral. The lowest, most acidic, average pH value was 6.27 measured at Bradley Lake in Andover whereas; the highest, most basic, pH value was 9.04 measured at Hunkins Pond in Sanbornton. This extremely basic value is not normally measured in New Hampshire surface waters and is caused by photosynthetic by-products released during algal and cyanobacteria blooms. Although a large fluctuation in regional pH is not noticeable, visual inspection of the trend line indicates pH is becoming slightly more acidic.

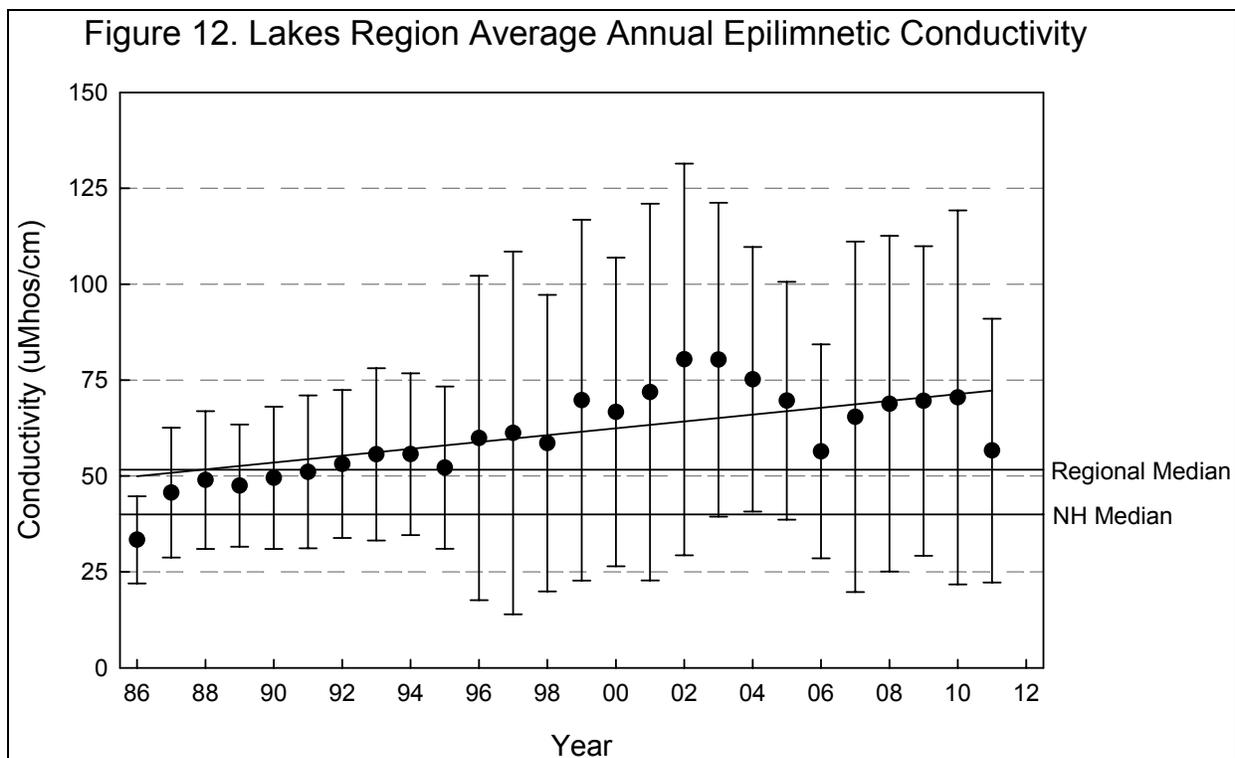
Variations in pH values between lakes and between different geographical regions may depend on the composition and weathering of underlying bedrock and the lake water chemistry. Another contributing factor to pH is acid deposition received as a result of emissions from power plants and vehicles. This increases levels of atmospheric carbon, nitrogen and sulfur which fall back to the earth in the form of acidic precipitation.



Annual and Historical Deep Spot Conductivity and Chloride Data Analysis

Conductivity is the numerical expression of the ability of water to carry an electric current, which is determined by the number of negatively charged ions from metals, salts, and minerals in the water column. The soft waters of New Hampshire have traditionally low conductivity values, generally less than 50 uMhos/cm. However, specific categories of good and bad levels cannot be constructed for conductivity because variations in watershed geology can result in natural fluctuations. **The median conductivity value for New Hampshire's lakes and ponds is 40.0 uMhos/cm. The median epilimnetic conductivity value for the Lakes region is 51.6 uMhos/cm.**

Figure 12 represents the 2011 average annual epilimnetic conductivity value at DLS lakes compared with the regional and state medians. The 2011 average epilimnetic conductivity value of the Lakes region was 56.6 uMhos/cm, which is slightly greater than the state median. Conductivity values fluctuate widely among the region's lakes. The lowest value of 12.2 uMhos/cm was measured at Cold Pond in Andover whereas the highest value of 204.0 uMhos/cm was measured at Turee Pond in Bow. A wide range of watershed types and degrees of development exists in the region. Cold Pond experiences very little developmental pressures, and is accessed by members of the Ragged Mountain Fish and Game Club. Turee Pond in Bow, although partially surrounded by forested land, receives stormwater runoff from residential development, paved roadways, parking lots and athletic fields. Overall, visual observation of the trend line indicates regional conductivity has increased over time.



Generally, conductivity values in New Hampshire lakes exceeding **100 uMhos/cm** indicate cultural, meaning human, disturbances. An elevated conductivity trend typically indicates point source and/or non-point sources of pollution are occurring within the watershed. These sources include failed or marginally functioning septic systems, agricultural runoff, and road runoff, and groundwater inputs. New development in the watershed can alter runoff patterns and expose new soil and bedrock areas, which could also contribute to increasing conductivity. In addition, natural sources, such as the mineral composition of bedrock, can influence conductivity.

The chloride ion (Cl^-) is found naturally in some surface and ground waters and in high concentrations in seawater. Research has shown that elevated chloride levels can be toxic to freshwater aquatic life. In order to protect freshwater aquatic life in New Hampshire, the state has adopted **acute and chronic** chloride criteria of **860 and 230 mg/L** respectively. The chloride content in New Hampshire lakes is naturally low in surface waters located in remote areas away from habitation. Higher values are generally associated with salted highways and, to a lesser extent, with septic inputs. **The median chloride value for New Hampshire's lakes is 4 mg/L. The median epilimnetic chloride value for the Lakes region is 12 mg/L.**

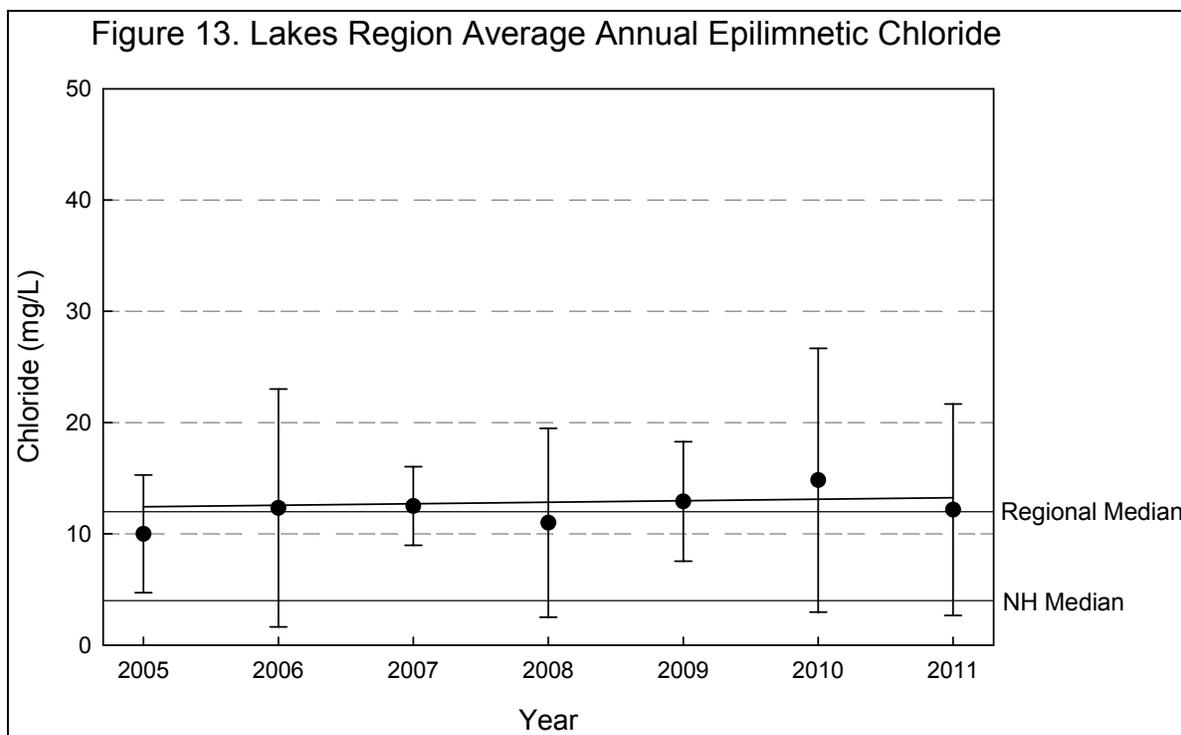


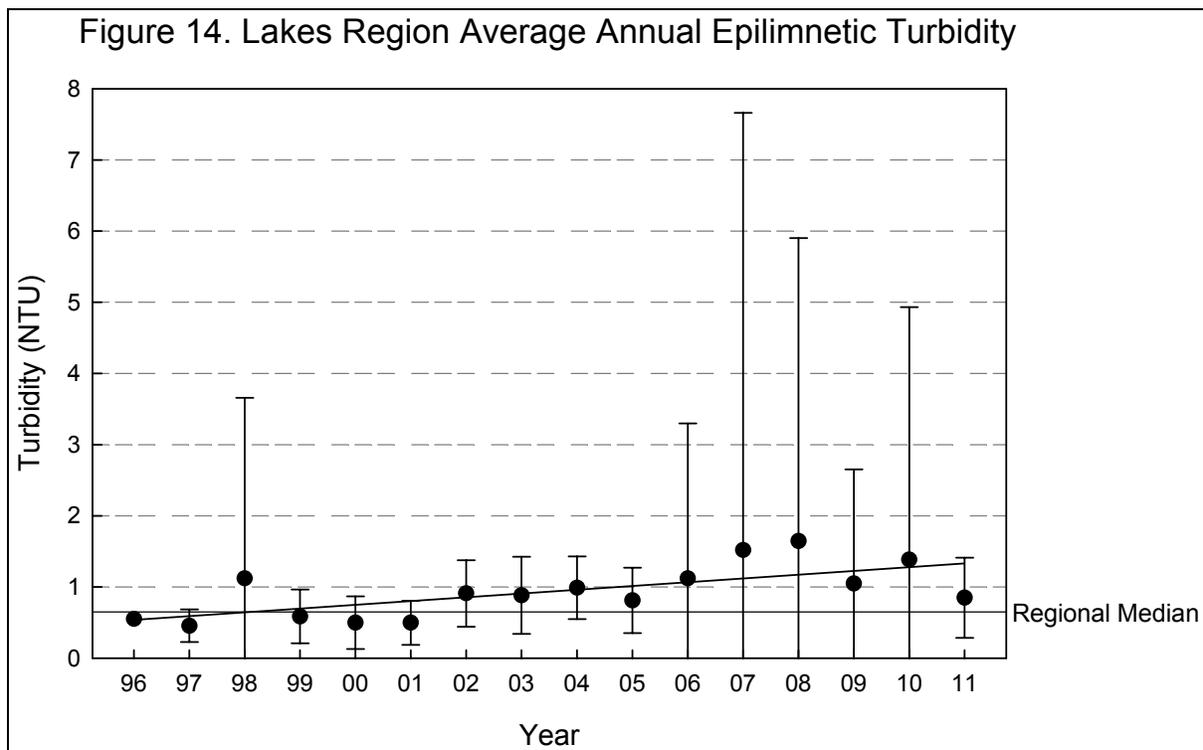
Figure 13 depicts average annual epilimnetic chloride levels for select regional lakes. The chloride measurement is relatively new for VLAP and is an optional analyte for participating lakes. Lakes that serve as water supplies or where conductivity levels may be influenced by chloride are analyzed annually. Average regional epilimnetic chloride levels generally range between 10 and 15 mg/L. Regional chloride levels are much less than the acute and chronic chloride criteria; however, they are greater than what we would typically measure in undisturbed NH surface waters.

Watershed management efforts to control un-natural sources of conductivity and chloride in waterbodies should employ a combination of best management practices in regards to winter salting practices. State and local governments and private homeowners should evaluate the use of road salt and alternatives to reduce the amount of material applied while maintaining public safety. *For additional information on the relationship between conductivity and chloride, please refer to Appendix A. For additional information on best management practices please refer to Appendix B.*

Annual and Historical Deep Spot Turbidity Data Analysis

Turbidity in the water is caused by suspended matter (such as clay, silt, and algae) that cause light to be scattered and absorbed, not transmitted in straight lines through water. Water clarity is strongly influenced by turbidity. **The Class B surface water quality standard for turbidity is no greater than 10 NTUs over the lake background level. The median epilimnetic turbidity of the Lakes region is 0.65 NTU.**

Figure 14 represents the average annual epilimnetic turbidity for the Lakes region. The 2011 average epilimnetic turbidity at Lakes region lakes was 0.85 NTU. Regional epilimnetic turbidity saw large spikes from 2006 through 2010 due to recurring cyanobacteria problems at French Pond in Henniker and Hunkins Pond in Sanbornton. Average regional epilimnetic turbidities during that period ranged from 1.05 to 1.65 however returned to more normal levels in 2011. New Hampshire has experienced more significant rainfall events in recent years which may also be contributing to an increase in stormwater runoff and turbidity in the region's lakes.



Elevated deep spot turbidity levels are typically the result of stormwater runoff, algal or cyanobacteria blooms, and/or disturbance of lake bottom sediments. Stormwater BMPs should be implemented when possible to reduce the amount of suspended sediments and debris transported to surface water. Boating activity in shallow areas should adhere to rules specified by the NH Marine Patrol in regards to speed and no wake zones. If an algal or cyanobacteria bloom is observed, please contact DES immediately. *For additional information on stormwater BMPs, boating, algae, and cyanobacteria please refer to Appendices A and B.*

Reference:

- Gibbs, J. P., Halstead, J. M., Boyle, K. J., & Huang, J. (2002). An hedonic analysis of the effects of lake water clarity on new hampshire lakefront properties. *Agricultural and Resource Economics Review*, 31(1), 39-46.
- Loder, A. (2011, September 08). *Vacation communities and the rest of new hampshire: How their tax rates compare*. Retrieved from <http://stateimpact.npr.org/new-hampshire> 2/27/2012
- Nordstrom, A. The New Hampshire Lakes, Rivers, Streams and Ponds Partnership, (2007). *The economic impact of potential decline in new hampshire water quality: The link between visitor perceptions, usage and spending*
- Sundquist, D. Society for the Protection of New Hampshire Forests, (2010). *New hampshire's changing landscape 2010*
- The Society for the Protection of New Hampshire Forests, (1999). *The economic impact of open space in new hampshire*